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Integrating New Bellhop Functionality into the Environmental Modelling Manager

Call-Up 006 on System Test Bed Software Design/Integration Standing Offer Arrangement — W7707-098179/001/HAL

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PWGSC Contract No: Call-up W7707-4500820247 on Contract W7707-098179/001/HAL
Contract Scientific Authority: Dale D. Ellis, (902) 426-3100 ext. 104

Defence R&D Canada – Atlantic

Contract Report
DRDC Atlantic CR 2011-253
September 2012

Canada

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September 2012

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Abstract

DRDC Atlantic has been developing a research-level acoustic prediction system, the System Test Bed (STB), in support of tactical decision aids and improving operator effectiveness. Within the STB, the Environment Modeling Manager (EMM) is a client-server system that provides a human interface for an operator to request various types of Environmental Analysis (EA) – such as the transmission loss, signal excess, etc. The EMM then manages behind-the-scenes calls to the Bellhop acoustic prediction engine, and when the results are ready, it displays them in the graphic format selected by the operator. The EMM/EA is currently a passive-only system, predicting how sound would propagate from a distant vessel to a receiver. Recently, the Bellhop program has been enhanced to handle the performance modelling of active sonar operations. The subject of the present call-up is to upgrade the STB/EMM/EA with the most recent Bellhop program release and to enable the active-sonar analysis capability and towed-array receiver beam patterns.

Résumé

RDDC Atlantique a mis au point un système de prédiction acoustique de recherche, le Banc d'essai de systèmes (*System Test Bed,* STB), dans le but d'appuyer le développement d'aides à la prise de décisions tactiques et l'amélioration de l'efficacité de l'opérateur. Dans le STB, l'EMM (Environment Modeling Manager – *gestionnaire de modélisation de l'environnement*) est un système client-serveur offrant une interface qui permet à un opérateur de demander divers types d'analyses environnementales (*Environmental Analysis*, EA), comme l'analyse de la perte de transmission, de l'excès de signal, etc. L'EMM gère ensuite les appels d'arrière-plan au moteur de prédiction acoustique Bellhop; lorsque les résultats sont prêts, elle les affiche dans le format graphique choisi par l'opérateur. L'EMM/EA était auparavant un système exclusivement passif qui prédisait la façon dont le son se propage à partir d'un navire lointain jusqu'à un récepteur. Récemment, le programme Bellhop a été amélioré afin de lui permettre de modéliser la performance des sonars actifs. La présente commande vise la mise à niveau du STB/EMM/EA avec la plus récente version du programme Bellhop et l'ajout d'une capacité de modélisation de sonar actif et de diagrammes de faisceaux de récepteurs à réseau remorqué.

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Executive summary

Integrating New Bellhop Functionality into the Environmental Modelling Manager

Terry J. Deveau; DRDC Atlantic CR 2011-253; Defence R&D Canada – Atlantic; September 2012

Introduction or background: DRDC Atlantic has been developing a research-level acoustic prediction system, the System Test Bed (STB), in support of tactical decision aids and improving operator effectiveness. Within the STB, the Environment Modeling Manager (EMM) is a client-server system that provides a human interface for an operator to request various types of Environmental Analysis (EA) – such as the transmission loss, signal excess, etc. Within the EMM an enhanced version of the Bellhop ray-based model is used for the acoustic propagation calculations. The EMM then manages behind-the-scenes calls to the Bellhop acoustic prediction engine, and when the results are ready, it displays them in the graphic format selected by the operator.

Results: The EMM/EA has been a passive-only system, predicting how sound would propagate from a distant vessel to a receiver. Recently, the Bellhop program has been enhanced to handle the performance modelling of active sonar operations. This work utilizes a specialized and enhanced version of the Bellhop model, derived by Dr. Diana McCammon, under contract to DRDC Atlantic, from the publicly-available source code originally developed by Michael Porter and published by the Ocean Acoustics Library, with the support of the U.S. Office of Naval Research. This call-up under the STB standing offer has upgraded the STB/EMM/EA with the most recent Bellhop program release and enabled the active-sonar analysis capability and towed-array receiver beampatterns.

Significance: This work gives the System Test Bed (STB) the capability of modelling the operation of both passive and monostatic-active sonar systems, including receiver vertical beampatterns, with flexible and quasi-realistic environmental inputs.

Future plans: A number of recommendations, with estimates of the level of effort required, for enhancements to the STB have been made in the final section of the report. Testing these enhancements in real-world at-sea trials and integration into Canada's PLEIADES Sonar system is the ultimate goal.

Sommaire

Integrating New Bellhop Functionality into the Environmental Modelling Manager

Terry J. Deveau; DRDC Atlantic CR 2011-253; R & D pour la défense Canada – Atlantic; septembre 2012.

Introduction : RDDC Atlantique a mis au point un système de prédiction acoustique de recherche, le Banc d'essai de systèmes (*System Test Bed,* STB), dans le but d'appuyer le développement d'aides à la prise de décisions tactiques et l'amélioration de l'efficacité de l'opérateur. Dans le STB, l'EMM (Environment Modeling Manager – *gestionnaire de modélisation de l'environnement*) est un système client-serveur permettant à un opérateur de demander divers types d'analyses environnementales (*Environmental Analysis*, EA), comme l'analyse de la perte de transmission, de l'excès de signal, etc. Dans l'EMM, une version améliorée du modèle à rayons Bellhop sert à réaliser les calculs de propagation acoustique. L'EMM gère ensuite les appels d'arrière-plan au moteur de prédiction acoustique Bellhop; lorsque les résultats sont prêts, elle les affiche dans le format graphique choisi par l'opérateur.

Résultats : L'EMM/AE était auparavant un système exclusivement passif qui prédisait la façon dont le son se propage à partir d'un navire lointain jusqu'à un récepteur. Récemment, le programme Bellhop a été amélioré afin de lui permettre de modéliser la performance des sonars actifs. Ces travaux font appel à une version spéciale améliorée du modèle Bellhop mise au point par Diana McCammon, dont RDDC Atlantique a retenu les services, à partir du code source disponible publiquement développé par Michael Porter et publié par l'Ocean Acoustics Library avec l'appui de l'U.S. Office of Naval Research. Cette commande subséquente à l'offre à commandes du STB visait la mise à niveau du STB/EMM/EA avec la plus récente version du programme Bellhop et l'ajout de la capacité de modélisation de sonar actif et de diagrammes de faisceaux de récepteurs à réseau remorqué.

Portée : Ces travaux donnent au STB la capacité de modéliser le fonctionnement de systèmes sonar monostatiques passifs et actifs, y compris le diagramme de faisceau vertical du récepteur, avec des données environnementales d'entrée souples et quasi réalistes.

Recherches futures : Un certain nombre de recommandations d'améliorations du STB ont été indiquées dans la section finale du présent rapport; elles sont accompagnées du niveau d'effort prévu. Le but ultime est de mettre à l'essai ces améliorations au cours d'essais réels en mer et de les intégrer au système sonar canadien PLEIADES.

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Acknowledgements

Dr. Dale Ellis was the scientific authority and Gary Inglis was the principal engineer overseeing this work. Dr. Ellis provided the contractor with the latest source code releases of the DRDC Bellhop program. Mr. Inglis provided the contractor with two releases of the STB source code (versions 1.2 and 1.3) during the course of this contract. In STB release 1.3, Mr. Inglis supplied a Fortran-to-C++ source code interface that greatly facilitated the work of the contractor in fulfilling the requirements of the contract.

This work utilizes a specialized and enhanced version of the Bellhop model, derived by Dr. Diana McCammon, under contract to DRDC Atlantic. Dr. McCammon's starting point was the publicly-available source code originally developed by Michael Porter and published by the Ocean Acoustics Library, with the support of the U.S. Office of Naval Research.

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1 Introduction

DRDC Atlantic has been developing a research-level acoustic prediction system, the System Test Bed (STB), in support of tactical decision aids and improving operator effectiveness. Within the STB, the Environment Modeling Manager (EMM) is a client-server system that provides a human interface for an operator to request various types of Environmental Analysis (EA) – such as the transmission loss, signal excess, etc. The EMM then manages behind-the-scenes calls to the Bellhop acoustic prediction engine, and when the results are ready, it displays them in the graphic format selected by the operator. The EMM/EA is currently a passive-only system, predicting how sound would propagate from a distant vessel to a receiver.

The publicly-available source code for the Bellhop propagation model was originally developed by Michael Porter and is published by the Ocean Acoustics Library, with the support of the U.S. Office of Naval Research. The version of Bellhop used in STB/EMM/EA, however, is a specialized and greatly enhanced version, developed by Dr. Diana McCammon under contract to DRDC Atlantic [1]. The biggest enhancement is the capability for active sonar modelling [2].

The subject of the present call-up under the STB Standing Offer was to upgrade the STB/EMM/EA with the most recent Bellhop program release. This work was done in collaboration with the Scientific Authority, Dr. Dale Ellis, and the Scientific Adviser, Mr. Gary Inglis. As part of the work of integrating the new Bellhop functionality into STB/EMM/EA, JASCO was tasked as follows:

- Task 1 - Update the EMM-to-Bellhop communications routines to handle the new input format for passive sensors.
- Task 2 - Add the necessary functionality to properly provide active-sensor input parameters to Bellhop.
- Task 3 - Update EMM to provide the necessary information to Bellhop so correct towed array beampatterns are employed in the acoustic prediction process.
- Throughout the execution of these three tasks to also update the EMM displays to handle the new functionality, as required and in consultation with the Scientific Authority (Dale Ellis) and/or Scientific Advisor (Gary Inglis).

2 Implementation

Following the issue of Call-Up 006 under the STB Standing Offer, a kick-off meeting was held at DRDC Atlantic on 10 Feb 2011. The logistics of the work were discussed, including the issues of getting the latest source code versions of STB and Bellhop for JASCO to work with. It was decided at that time to set up a SharePoint access permission for specific JASCO personnel on the DRDC Atlantic SharePoint server. This SharePoint server would then serve as a medium of exchange for source code and documentation files between JASCO and DRDC Atlantic on matters pertaining to the STB Call-Up.

The SharePoint access was implemented quickly and worked well with no issues. The preliminary versions of the source code and documentation files were exchanged and JASCO proceeded to investigate and plan how to carry out the Bellhop upgrade to STB.

The final version of the new Bellhop source became available at DRDC Atlantic on 29 Mar 2011 and was made available to JASCO via SharePoint on 31 May 2011.

Release 1.2 of the STB source code was made available to JASCO early in March 2011. We found a number of issues with this release of the code and had difficulty getting it installed and running EMM/EA test runs of Bellhop even before making any attempts to perform the upgrade. A delay arose due to the unavailability of the Scientific Advisor to this Call-Up, Gary Inglis, while he was away at sea on other projects.

An extension to the end-date of the call-up was requested in view of the various delays and constraints that had arisen. The call-up end date was then extended to 31 Aug 2011.

The Scientific Advisor, Gary Inglis, provided JASCO with release 1.3 of the STB source code on 29 Jul 2011. This immediately cleared-up most of the issues that we had been struggling with. This release already included a source code interface between STB (in C++) and passive Bellhop (in Fortran). Work proceeded quickly at that point towards completing the remaining tasks in the Call-Up.

Tasks 1 and 3 were fully completed. However, at the very end, the call-up funding was exhausted with a small amount of work remaining on Task 2. Since another call-up has already been started for additional work on the STB Standing Offer, the work of completing the final integration of Active Bellhop in STB will be performed under the new call-up.

2.1 Issues

There are three main issues involved in the integration of DRDC Bellhop with STB, (1) Fortran compiler issues, (2) the mechanism for passing data back and forth between program modules written in C++ (EMM/EA) and program modules written in Fortran (Bellhop), and (3) changing from a file-based data-passing mechanism to a memory-block data-passing mechanism.

The last two are related to each other. DRDC Bellhop was designed to use an ASCII file-based data-passing mechanism because of its transparency and ease of direct manipulation by a human

operator, usually a scientist, who wants to be able to see and control the inputs and outputs of individual Bellhop runs. However, when Bellhop is integrated into STB, the ASCII file-based interface becomes a disadvantage. STB needs to be able to execute many Bellhop runs as quickly as possible. Using ASCII files to exchange all the data, with extensive system file I/O overhead entailed, would introduce an unnecessary constraint and drag on computer resources, with no advantage in doing so, since direct human inspection and manipulation of the input and output files is neither practical nor desired.

The mechanism of passing data by memory-block is much more efficient in its use of computer resources. It does entail one problem, however, in that a general-purpose Fortran language interface to a data-passing by memory-block mechanism is not included in STB. This was solved by building a specific memory-block data-passing interface in STB just to exchange data between EMM/EA (written in C++) and the individual Bellhop executables (written in Fortran).

DRDC provided JASCO with this interface for the passive Bellhop program. JASCO then used it as a pattern to construct a similar interface for the two active Bellhop programs.

2.2 Fortran Issues

Bellhop, like many numerical analysis programs written in Fortran, attempts to employ single precision floating point for most variables that do not require double precision. That is to say, variables are only declared to be double precision if it is necessary to ensure numerical accuracy and stability of the computations. This is considered to be good programming practice in numerical analysis software, especially in Fortran.

The situation is complicated by the need to support both 32-bit and 64-bit native word size machine implementations of the software. Depending on compiler switches and exactly how single versus double precision was specified in the source code, differences can arise under 64-bit implementation which were not present under 32-bit implementation (or vice versa).

In order to avoid possible problems of this nature, the STB version of DRDC Bellhop Fortran source code was changed to use double precision (`REAL*8` syntax) for all floating point variables.

There is also an issue with word size of integer variables (“`INTEGER*4`” vs. “`INTEGER*8`” in Fortran) in supporting a single set of source code files that will work correctly whether they are compiled for a 32-bit or a 64-bit target machine. The STB version of the Bellhop source code explicitly declares “`INTEGER`” type for all integer variables in Fortran, which the `gfortran` compiler normally implements as 32-bit integers; however, STB forces their promotion to 64-bit integers on 64-bit hardware using a compiler switch that is activated in the `Makefile`. This mimics the treatment of the “`long`” integer type in C++, which the `gcc` compiler likewise implements as 32-bit or 64-bit integers, according to the machine word size.

Finally, there is one additional minor Fortran issue, as the DRDC Bellhop source code includes free-form structure, extends beyond column 72, etc. The following `gfortran` compiler flags were used in the `Makefile` to avoid compiler syntax errors:

```
-Wall -O2 -g3 -fmessage-length=0 -ffree-form -ffree-line-length-none -std=legacy
```

2.3 Data Passing Mechanism

DRDC Bellhop uses Fortran Data Modules to pass data between its own program elements (i.e., subroutines and functions). The interface to STB involves new C++ procedures that are called from existing STB C++ procedures, and that move data values back and forth between STB data structures (i.e., C++ structures) and the Fortran Data Modules that are used by DRDC Bellhop.

Each variable in the Fortran Data Module is automatically given an entry in the linker symbol table by the Fortran compiler. This is equivalent to the "`extern`" declaration in C++. The programmer must therefore construct a list of these "`extern`" symbol names in a C++ source file that matches the linker symbol names assigned by the Fortran compiler to the variables in the Fortran Data Modules, and the variable type must also match (e.g, "`long`" matched with "`INTEGER`", "`double`" matched with "`REAL*8`", etc.)

The C++ procedure can then exchange data between C++ structures and the Fortran Data Modules by means of the C++ assignment operator "=" and the "`extern`" variables from the C++ source files that reference the Fortran Data Module variables.

2.4 Replacing File Passing with Memory Block Passing

DRDC Bellhop uses a Fortran subroutine or program named "`frontend...`" to read a set of ASCII input files, make calls to the Bellhop computational subroutines, and write a set of ASCII output files. When integrating DRDC Bellhop with STB, these "`frontend`" programs are eliminated and the ASCII files are no longer used for program-level I/O. (In the case of `SE_v5`, however, the "`frontend`" functionality is distributed among different subroutines, all of which must be altered).

Instead of the "`frontend`" program, the STB integrated version of DRDC Bellhop uses "`interface`" Fortran subroutines to perform the equivalent tasks of calling the Bellhop computational subroutines, and the program-level file I/O is replaced by memory block data passing (see the previous section) in C++ procedures that are called from STB, and which in turn call the Fortran "`interface`" subroutines.

For example, STB calls the C++ procedure "`transmission loss`", which in turn sets the relevant input parameters in the Fortran Data Module variables (in some cases by calling subsidiary C++ procedures) via the C++ assignment operator "=" and "`extern`" declarations for the Fortran Data Module variables. It then calls the new Fortran subroutine "`bellhop_interface`", which takes the role of the former "`frontend_ray_TL_v4a`" Fortran program, except that it uses Fortran Data Modules variables that are set and queried in the C++ calling program, rather than reading and writing ASCII disk files to set and output their values.

3 Results

3.1 Task 1 — Update STB Bellhop for Passive Analysis

As a result of updating STB with the current version of DRDC Bellhop for Passive Analysis, EMM/EA execution in STB now uses the updated Bellhop routines in its passive analysis computations. Refer to the STB documentation [3] for instructions on how to install and run STB. When STB is first started, the `STATUS AND CONTROL` window will appear. From the left hand menu column, select `TASK` then `SUMMARY`; this will cause four additional windows to be loaded: `CHART`, `WORKSHEET`, `TEMPERATURE PROFILE`, and `ENVIRONMENTAL ANALYSIS` (see Figure 1).

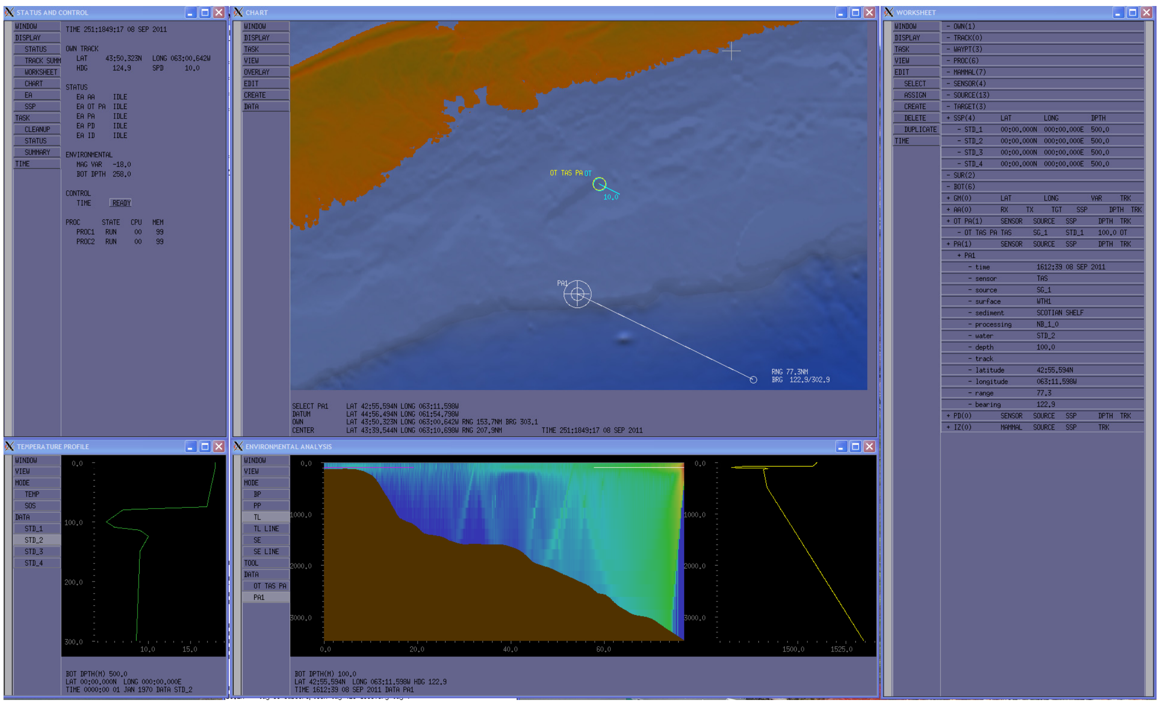

Figure 1. STB windows that appear when `TASK` -> `SUMMARY` *is selected.*

To perform a passive analysis, right-click on the map (in the `CHART` window); this will place a + at the cursor location, which will be the range zero sensor location. Then select `CREATE` and "`PA E`" on the chart menu bar (left hand column). A Passive Analysis (PA) chart symbol will be displayed (a yellow circle around the +, although the + isn't part of the symbol) and it will be labelled "`PA`*n*", where *n* is a sequential number.

If the PA chart symbol is right-clicked once, a yellow square is drawn around it to signify that is has been selected. If the PA chart symbol is right-double-clicked, the Line of Bearing (LOB) tool is displayed with it. Several PA chart symbols can be placed on the chart simultaneously. Figure 2 shows an example of a `CHART` window; `PA4` is a simple PA chart symbol, `PA3` is one that has been selected (note the square), and `PA5` has the LOB tool open.

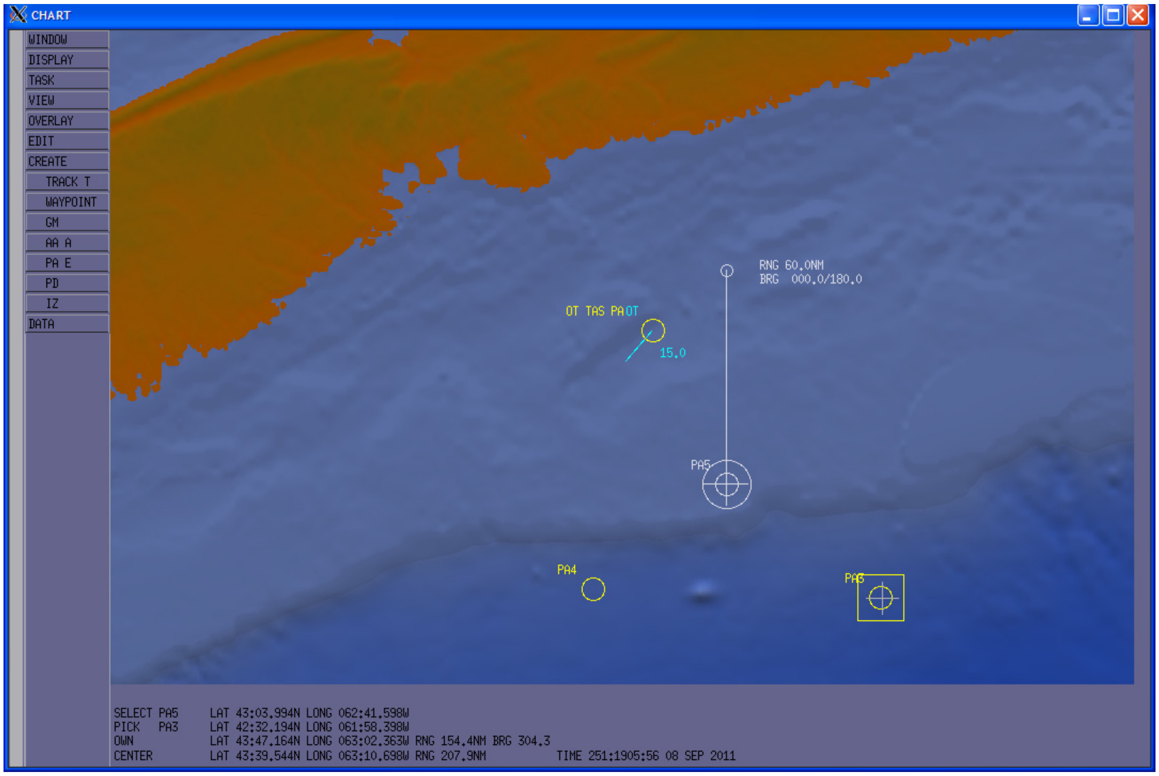

Figure 2. STB `CHART` *window with several PA symbols present.*

When the LOB tool is open on a PA chart symbol, the small white circle represents the source location (and the maximum range for the sensor) — the white line that joins them represents the LOB for the analysis. The source location (i.e., maximum sensor range and bearing) can be adjusted by right-click-and-drag on the small white circle.

The STB automatically runs the passive analysis as specified by the selected parameters. The operator doesn't explicitly initiate a run. The operator just selects the desired run parameters and the output products; the rest is automatic.

Several ocean temperature vertical profiles are available for selection in the `TEMPERATURE PROFILE` window, however, selecting a profile in this window only displays it visually to the operator, it doesn't actually select it for analysis. The selection for analysis is done in the `WORKSHEET`. Figure 3 shows an example of profile `STD_4` selected for display in the `TEMPERATURE PROFILE` window.

The "`PA(`*n*`)`" line is usually near the bottom of the `WORKSHEET`. When preceded by a "–" it is closed. When preceded by a "+" it is open, and the *n* individual PA parameter blocks are listed beneath it. Right-double-clicking on "`PA(`*n*`)`" toggles between open and closed modes. All the lines in the `WORKSHEET` can be opened or closed in an analogous manner.

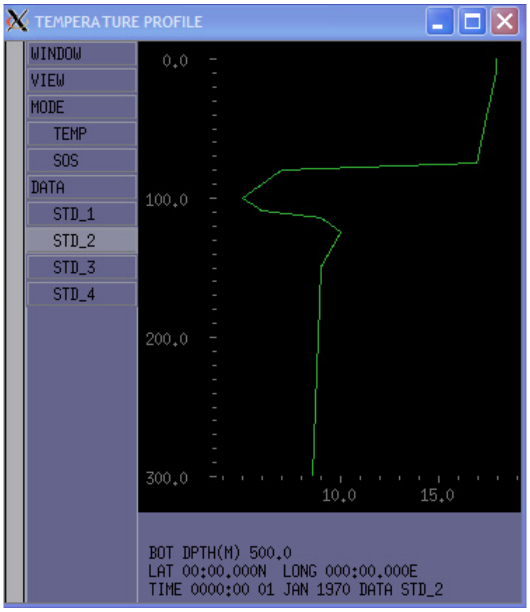

Figure 3. Example of `TEMPERATURE PROFILE` *window.*

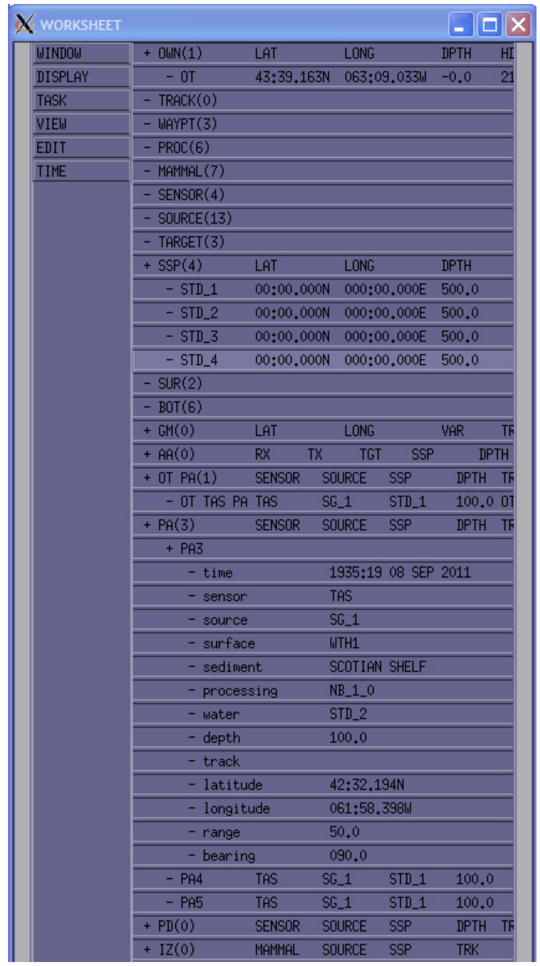

Figure 4. Example of `WORKSHEET` *window showing passive analysis parameters.*

Figure 4 shows an example of a `WORKSHEET` window with the "`+ PA(`*n*`)`" group open and the "`+PA3`" parameter block also open. Individual lines in the parameter block can be right-double-clicked to open them for editing. The line labelled "`- water`" was edited in this way, and the `STD_2` temperature profile was thereby selected for analysis with `PA3`.

Figure 5 shows `PA3` on the `CHART` with the LOB tool open and set to a source range of 50 nmi and bearing of 090 degrees. It also shows the `ENVIRONMENTAL ANALSYIS` transmission loss (`TL`) results for `PA3` (vertical axis is sensor depth, horizontal axis is sensor range along the LOB). Other `PA3` results can be selected at any time, such as the bottom profile (`BP`), ray trace diagram (`PP`), `TL line` plot (for the nominal sensor depth), signal excess (`SE`) based on ambient noise, and `SE line` plot (for the nominal sensor depth). The value labelled `BOT DPTH(M)` is actually the source depth.

Results for other `PA`*n* chart symbols can likewise be selected on the `ENVIRONMENTAL ANALYSIS` window at any time; and any of the other environmental or system specifications can also be

changed at any time. For example, right-click-and-drag on any `PA`*n* chart symbol will allow it to be moved around the map, and the LOB can likewise be adjusted at will, by click and drag on the small white circle. Any of the variables in the `WORKSHEET` can be opened and changed at any time, with nearly immediate updates appearing automatically in the results.

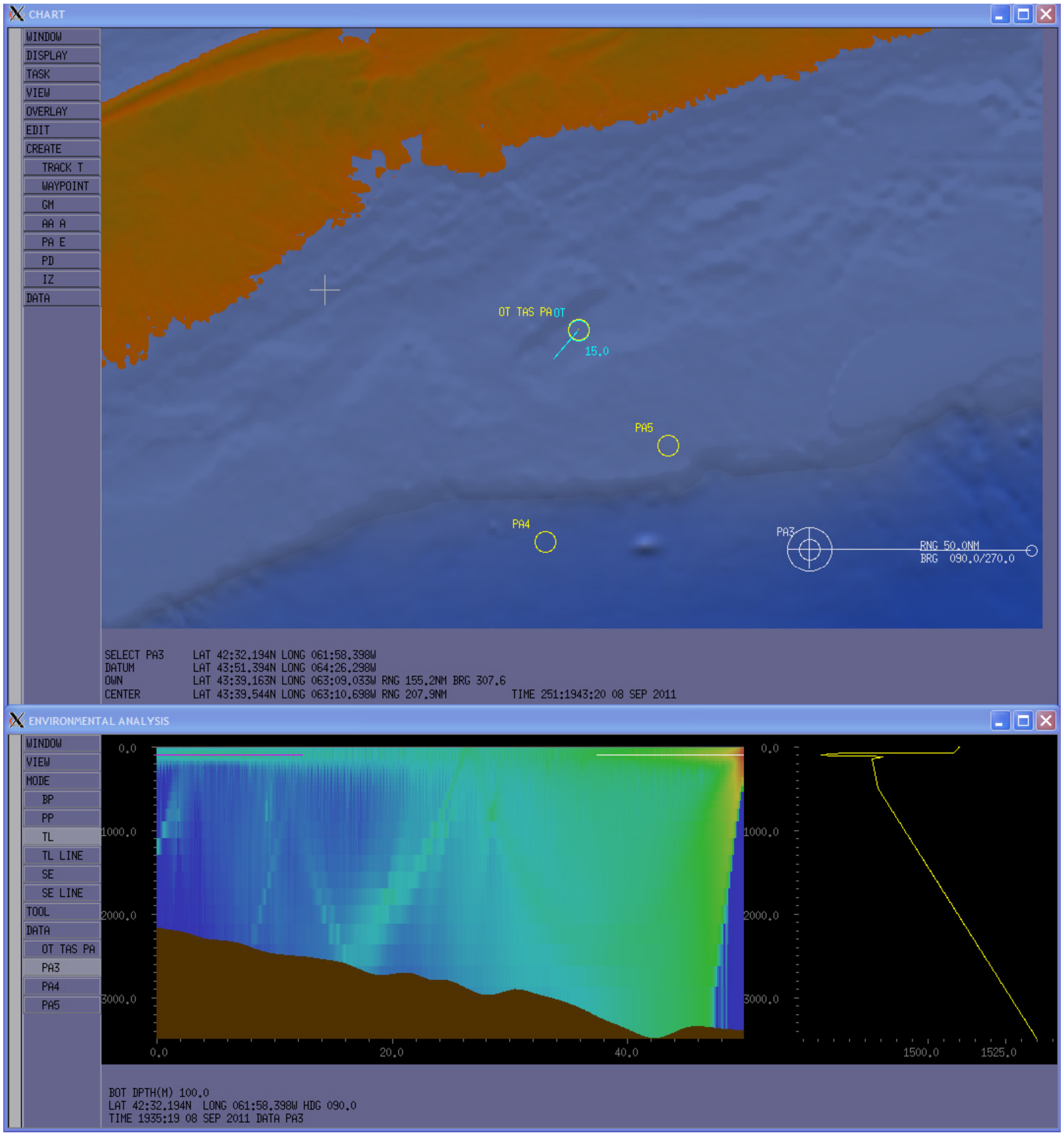

Figure 5. The `CHART` *and* `ENVIRONMENTAL ANALYSIS` *windows showing* `PA3` *transmission loss (*`TL`*) along a 50 nmi, 090 degree LOB.*

3.2 Task 2 — Implement Active Analysis Bellhop in STB

The procedures for performing active sonar analysis in STB/EMM/EA using the upgraded DRDC Bellhop active capability are almost exactly the same as the passive analysis procedures, as discussed in Section 3.1 above. The main difference is that to perform an active analysis, when you right-click on the map (in the `CHART` window) to place a + at the sensor location, you then must select `CREATE` and "`AA A`" on the chart menu bar (left hand column). An Active Analysis (AA) chart symbol will be displayed (a yellow circle around the +) and it will be labelled "`AA`*n*", where *n* is a sequential number. When the LOB tool is opened, the small white circle represents the maximum target range and the bearing of the target.

Also, there are additional variables that pertain to the active analysis that can be utilized in the `WORKSHEET` window. The "`+ AA(`*n*`)`" group can be opened and the "`+ AA`*n*" parameter block also opened to access the individual variables by right-double-clicking on them to open them for editing. Figure 6 shows an example of a `WORKSHEET` window and the parameter block for active analysis chart symbol `AA1` opened for access. The sensor and source can be separately selected (although geographically co-located in this monostatic implementation) and various pertinent parameters adjusted. The target can also be selected and its target strength adjusted.

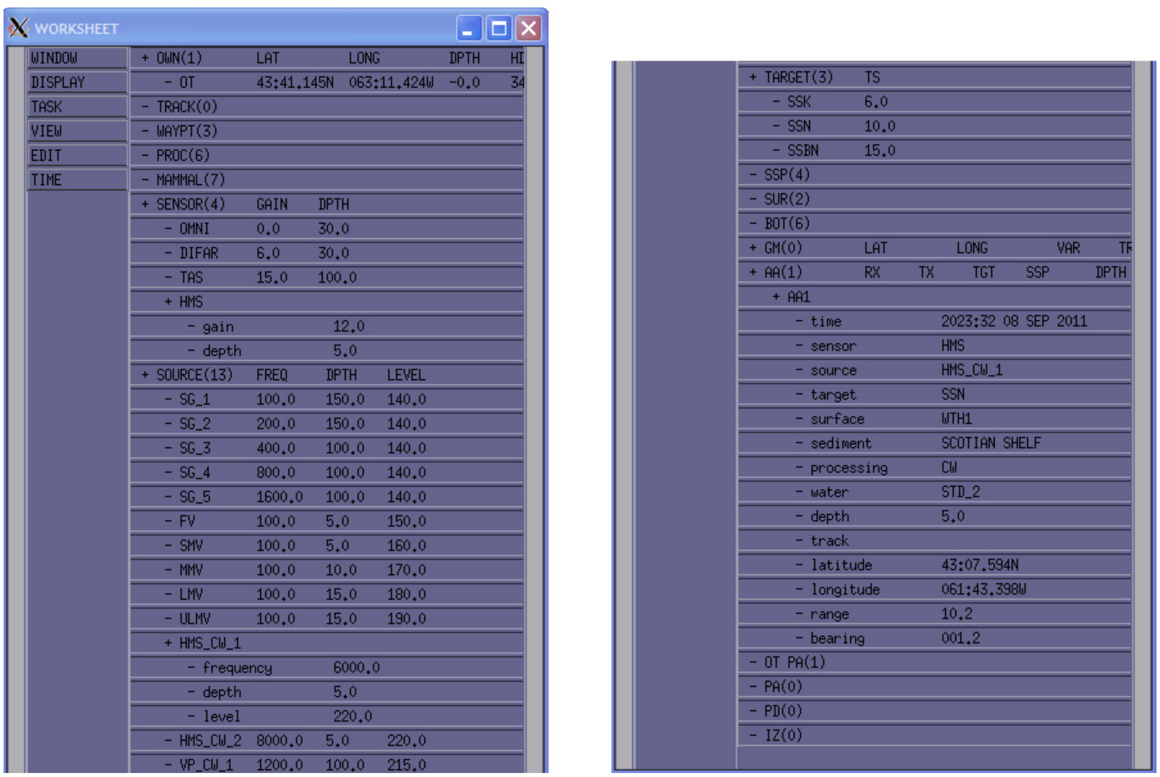

Figure 6. Example of `WORKSHEET` window showing active analysis parameters, split in two columns for display convenience.

The results of the active analysis are displayed in the `ENVIRONMENTAL ANALYSIS` window and the same sorts of plots are selectable as for passive analysis. See Figure 7 for an example.

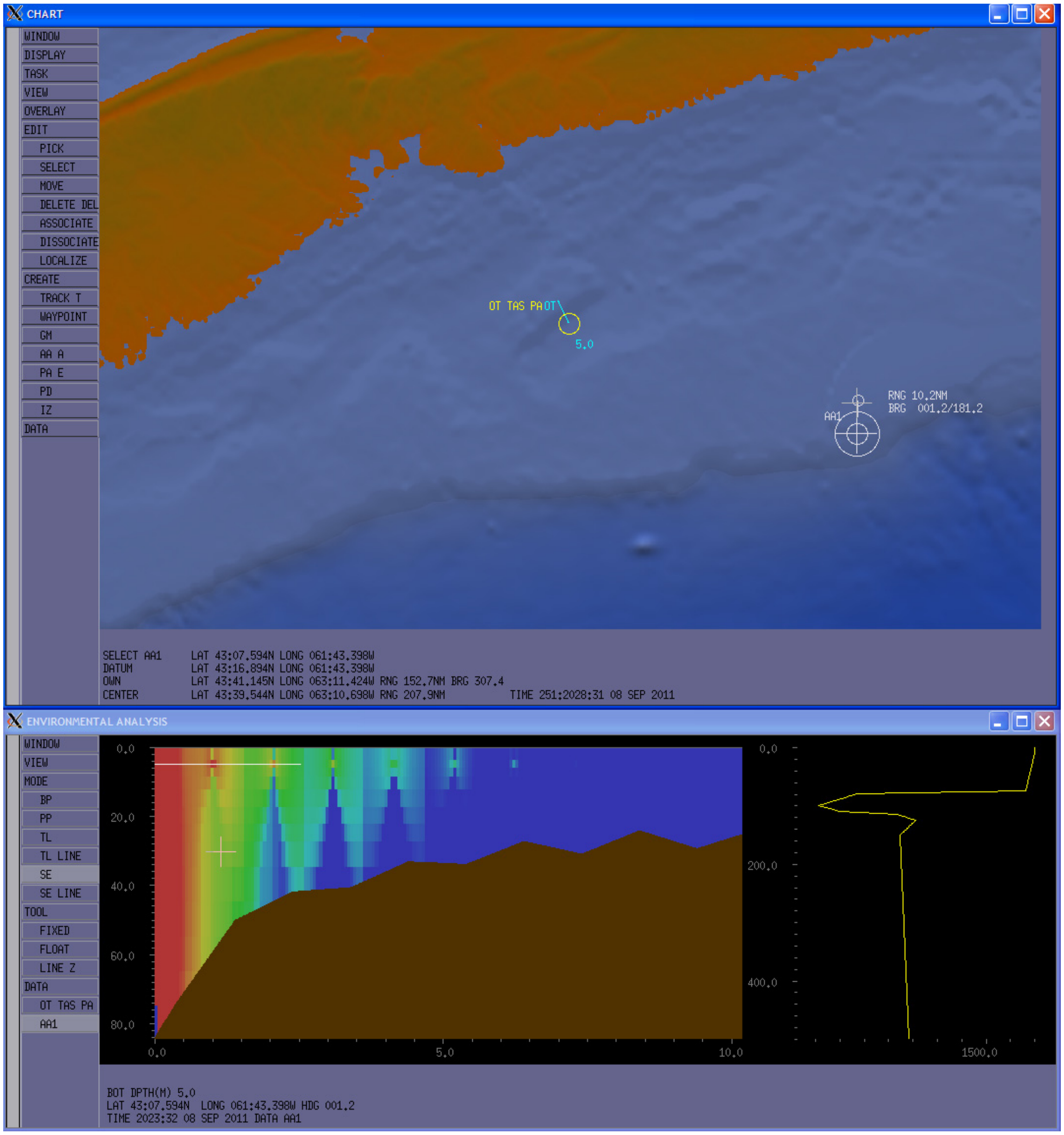

Figure 7. The `CHART` *and* `ENVIRONMENTAL ANALYSIS` *windows showing* `AA1` *signal excess (*`SE`*) along a 10.2 nmi, 001 degree LOB.*

The main difference between the results displays for passive and active analysis is that where the passive analysis shows the sensor depth on the vertical axis, sensor range on the horizontal axis, and the fixed source depth labelled "`BOT DEPTH(M)`" below it, the active analysis shows the target depth on the vertical axis, target range on the horizontal axis, and the fixed sensor/source depth labelled "`BOT DEPTH(M)`" below it. Also, under active analysis, the Signal Excess (SE) calculation uses the maximum of either reverberation or ambient noise in arriving at the masking level.

3.3 Task 3 — Implement Towed Array Vertical Beampatterns

The sensor vertical beampattern capability has been built into STB/EMM/EA by means of beampattern files, in ASCII format, of the same structure that standalone DRDC Bellhop uses. STB/EMM/EA uses a configuration file (in ASCII format) to associate a vertical beampattern file with each sensor name. There is an EMM/EA configuration file (e.g., `ea.demo/run/im.cfg`) that initially defines one towed array sensor named `TAS`, although additional sensor names can easily be added. The same directory (e.g., `ea.demo/run`) initially contains a number of vertical beampattern files, but again, new ones can be added at will. To associate one vertical beampattern file (e.g, `beampattern.inp`) with one sensor (e.g., `TAS`) the file `im.cfg` can be edited and the appropriate line in the file can be updated; e.g.:

```
$ITEM$   $DATA$   RX_03.RX   $MESSAGE$   "<data   name='TAS'   gain='15.0'
                                      depth='100.0' file='beampattern.inp' >"
```

(the above should be understood as one long line of text)

When an analysis run is initiated (which happens automatically if an input parameter is changed, new environmental data arrives, etc.), whether passive or active, STB/EMM/EA reads the contents of the vertical beampattern file that is associated with the selected sensor name, creates a memory block containing the vertical beampattern data, and passes this memory block to the C++ wrapper procedure that is responsible for loading the Fortran Data Module with this data, so it can be accessed from the DRDC Bellhop Fortran subroutines that are subsequently called. In the standalone version of DRDC Bellhop this vertical beampattern data would have been read in by the "`frontend...`" program and likewise loaded into the Fortran Data Module.

The following tests were performed to verify the correct functioning of the towed array beampattern integration. After editing the configuration file `ea.demo/run/im.cfg` to ensure that the sensors `TAS` and `OMNI` reference different vertical beampattern files (`beampattern.inp` and `omni_beampattern.inp`), a passive analysis run was tested twice, once with the `OMNI` sensor selected, and a second time with the `TAS` sensor selected; all other parameters were held constant. The differences between the `TL line` plots for the two runs are shown in Figure 8. The test was then repeated, as a control, with the same `omni_beampattern.inp` file specified for both the `TAS` and `OMNI` sensors (equivalent to the towed-array broadside beam) no differences were seen in the `TL line` plots for the two sensors in that case.

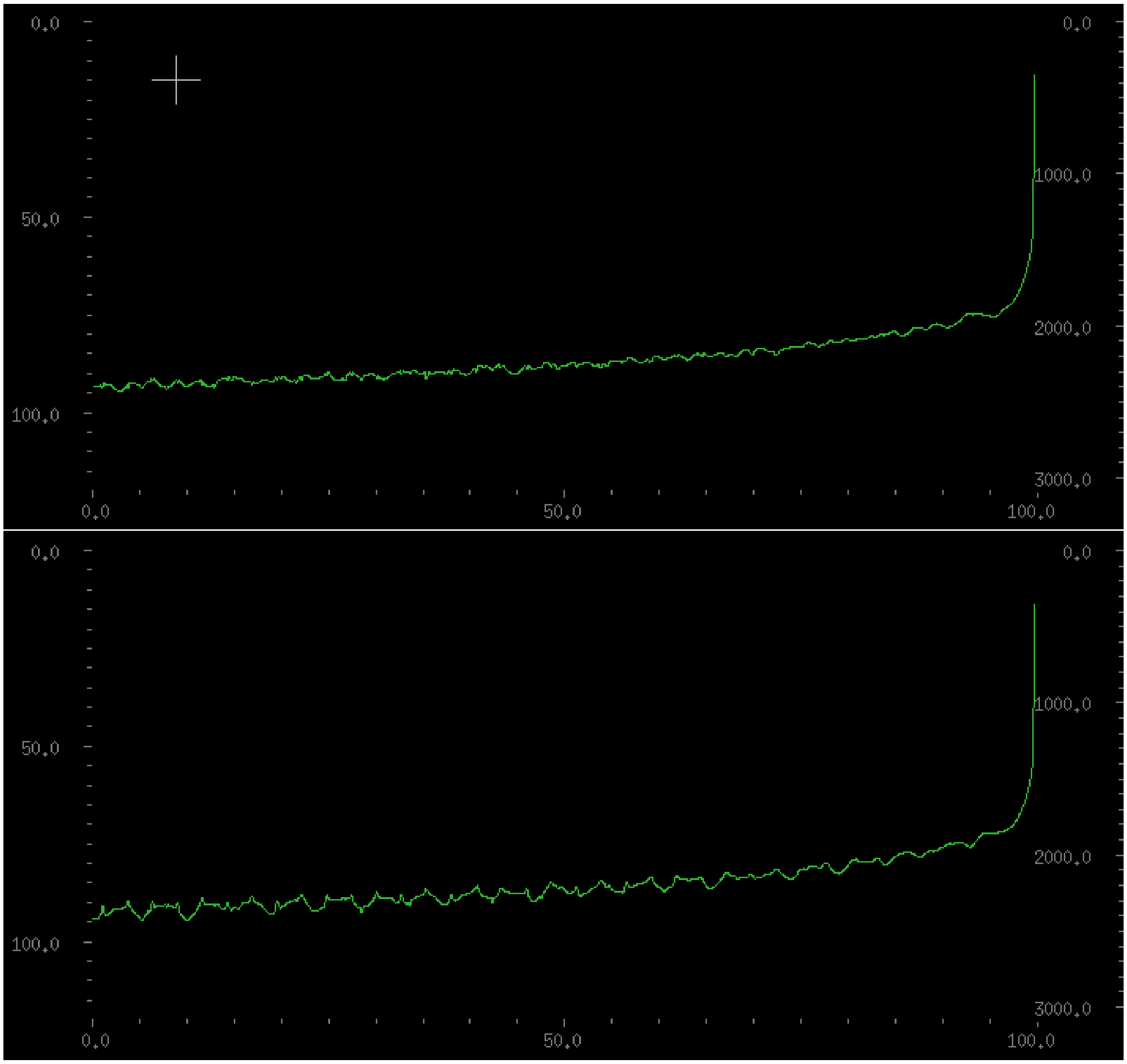

Figure 8. Transmission loss (TL) line graph showing differences between a passive analysis run with the `OMNI` *sensor (top) and the* `TAS` *sensor (bottom) when different vertical beampattern files have been associated with those sensor names in the* `im.cfg` *file.*

4 Conclusions

The latest version of the DRDC Bellhop model (both active and passive) has been integrated with STB/EMM/EA under this call up (call up 006 under the STB standing offer), including the capability of employing towed array beampatterns in the acoustic prediction process.

Some of the internal connections for parameters passed between STB and DRDC Bellhop in the active analysis case were not quite finished under this call up, due to the scope of work being bounded by a $30K fixed budget.

5 Recommendations

1. There is a small amount of work left to be done to complete the internal connections for passing the active analysis parameters from STB to DRDC Bellhop. The amount of remaining work is too small to require a separate call up of its own. It is recommended that this work be performed under the umbrella of the next STB call up. The level of effort required is a maximum of three days.

2. The DRDC Bellhop program provides a number of additional analysis options and capabilities that are not currently being utilized by STB. One example is the capability for bistatic active analysis. It is recommended that a study be done of everything that DRDC Bellhop can do and what changes would be required to STB in order for STB to use that capability. This would include an investigation of new output displays that could be added to STB to show results that DRDC Bellhop could make available (one example would be reverberation level versus range of simultaneous echo arrival). The level of effort required for this study would be roughly four weeks.

3. Some of the displays in STB currently have axes that are unlabelled or are poorly labelled, and that cause confusion. The label "`BOT DPTH(M)`" in the `ENVIRONMENTAL ANALYSIS` window is a particularly confusing example; it never means bottom depth, but it can mean either source depth or sensor depth, depending on whether active or passive analysis is being displayed. Another example is the "`SOS`" `MODE` of the `TEMPERATURE PROFILE` display, which one might expect to mean "Speed of Sound", but actually appears to represent "Salinity of Seawater". On this, and many of the other displays, the axis units are not shown, which adds to the confusion. It is recommended that STB be improved to show axis labels with units on all displays, and that other labels be improved to be clear and unambiguous. The level of effort required for this work is estimated to be roughly two weeks.

4. This call up has implemented towed array vertical beampatterns via a beampattern input file, which is how they are also implemented in DRDC Bellhop. It would be useful, however, to have an option in STB to automatically generate the vertical beampattern file, based on the array specifications (array heading, number of elements, spacing, etc.) and the LOB of interest. As it stands now, a separate vertical beampattern file would have to be externally prepared in advance for each towed array configuration and each relative source bearing angle, and then the appropriate file manually selected for each LOB. Most of the effort required to accomplish this enhancement would be related to extending the STB user interface to accommodate the additional controls. The level of effort required for this work is estimated to be roughly four weeks.

References

[1] Diana F. McCammon, *BellhopDRDC Users Guide, Version 3*, Contract Report, DRDC Atlantic CR 2006-067, September 2006.

[2] Diana F. McCammon, *Users Guide to BellhopDRDC_active_v5 and Updated Passive 4a*, Contract Report, DRDC Atlantic CR 2010-319, January 2011.

[3] Gary Inglis, *Release Notes for System Testbed (STB) v1/3*, README file, DRDC Atlantic, *Private Communication*, 28 July 2011.

List of symbols/abbreviations/acronyms/initialisms

AA	Active Analysis
ASCII	American Standard Code for Information Interchange
BP	Bottom Profile
DND	Department of National Defence
DRDC	Defence Research & Development Canada
EA	Environmental Analysis
EMM	Environmental Modelling Manager
LOB	Line of Bearing
nmi	Nautical Mile (1852 m)
PA	Passive Analysis
SA	Scientific Authority
SE	Signal Excess
STB	System Test Bed
TL	Transmission Loss

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DRDC Atlantic has been developing a research-level acoustic prediction system in support of tactical decision aids and improving operator effectiveness, the System Test Bed (STB). Within the STB, the Environment Modeling Manager (EMM) is a client-server system that provides a human interface for an operator to request various types of Environmental Analysis (EA) – such as the transmission loss, signal excess, etc. The EA then manages behind-the-scenes calls to the Bellhop acoustic prediction engine, and when the results are ready, it displays them in the graphic formats selected by the operator. The EMM/EA is currently a passive-only system, predicting how sound would propagate from a distant vessel to a receiver. Recently, the Bellhop program has been enhanced to handle the performance modelling of active sonar operations. The subject of the present call-up is to upgrade the STB/EMM/EA with the most recent Bellhop program release and to enable the active-sonar analysis capability and towed-array receiver beam patterns.

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Bellhop, Environmental Modelling Manager, System Test Bed, PLEIADES, ray tracing, underwater acoustics, propagation, beam patterns

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